Short term solution

Lucent Technologies
Bell Labs Innovations

- **FER is major contributor to CER**
- **The goal is to Maintain the FER as close to 0% as possible**
  - Make TTY mobile as a high power mobile
    - Transmit more power on the reveres link to achieve "0 %" FER
    - Allow the forward power control to transmit more power on the forward link to achieve "0 %" FER
    - Impacts system capacity

TTY/TDD Compatibility Measurements
(Preliminary Results)

by

Mohamed El-Rayes

5.20.98

POSSIBLE CAUSES OF ERRORS

- Coupling:
  - Acoustic coupler: ambient noise susceptability
  - Non-optimal direct interface: Impedance,...
- DSP Baseband functions:
  - Echo supression
  - Noise Cancellation
  - Equalization
- Vocoder Parameters:
  - Vocoder Rate
  - Vocoder Delay

POSSIBLE CAUSES OF ERRORS (Cont'd)

- Link Conditions:
  - Signal Quality
  - White Noise
  - Fading depth
  - Co-Channel Interference
  - Adjacent Channel Interference
  - Others
- Network Factors:
  - Network Vocoders
  - Link Symmetry
  - Others

AMPS MEASUREMENTS

- Analog was tested to provide bench mark
- Connection via an existing interface box
- Actual network was used (Dalas, Texas)
- RX Signal quality was approx. -90 dBm
- Handset sent 590 characters, no errors
- Handset received 590 charcters, one error
- Asymmetrical link?
- Generally, character error rate < 1%

PCS1900 MEASUREMENTS

- Connection via an existing interface box
- Several PCS1900 (GSM) phones were tested using an internal basestation (no network effects)
- No errors were reported (except for an extra space every once in a while)
- Similar measurements were made with Ericsson last March, errors were 2-4%
- Link quality was good, approx. -60 dBm
- Next, test under variable link conditions/fading
- Also, test in actual network
- Vocoder rate is 13 Kbps

TDMA MEASUREMENTS

- Connection via an existing interface box
- Several TDMA (DAMPS) phones were tested using an actual network (Dallas, Texas)
- RX Signal quality ranged from -95 to -60dBm
- Handset sent 590 characters, errors > 10%
- Handset received 590 charcters, errors > 10%
- Asymmetrical link?
- Disabled DSP baseband functions: Echo cancellation, noise, equalization: no effect

TDMA MEASUREMENTS (Cont'd)

- Optimize signal level into vocoder (< 5% distortion)
- Try to optimize interface box
- Character error rate at AMPS mode < 1%
- The Vocoder rate is 7.4 Kbps (EFR)
- TR45.3 will mandate US1 Vocoder (12.4 Kbps)
- Future Solution: Completely bypass Vocoder?
- Next, improve interface box
- Next, increase baud rate

CDMA MEASUREMENTS

- Tests were done using an acoustic coupler
- Acoustic coupler was prone to ambient noise
- Vocoders were evaluated by either field tests or using simulation
- All simulated results did not look good (EVRC)
- Field testing was more successful (< 10% errors)
- Currently, CDMA networks use fixed 13 Kbps
- Eventually, EVRC will be used for capacity

CDMA MEASUREMENTS (Cont'd)

- Can we fix rate for TTY?
- In General, results were good up to 200 Bauds
- If > 200 Bauds, errors > 10%
- Solution: TR45.5 FAX standard for CDMA WLLs (CDMA Wireless Local Loops)
- Measurements were only made at 800 MHz
- Next, repeat using interface box
- Next, repeat at 1900 MHz

CONCLUSIONS

- Based on these preliminary results: it is more likely that the vocoder rate has a major effect
- Direct connection is more robust
- Possible Future Solutions:
  - ITU-T V.18
  - TR45.3 (TDMA): US1 Vocoder (12.4 Kbps)
  - Completely bypass Vocoder?
  - Can we fix rate for CDMA networks?
  - TR45.5 FAX standard for CDMA WLLs

Motorola CSS TTY Testing Summary

Character Error rates in %

system	mobile-mobile	mobile to L.L.	L.L to mobile	B.S. hardware	Mobile hardware
Analog		1%			Motorola
CDMA F.R. 13k	17%	12%		Motorola B.S.	Motorola
TDMA		6%	12%	Ericsson B.S.	Motorola
GSM 1900 F.R.	>50%	23%	>50%	Ericsson B.S.	Motorola
GSM 1900 E.F.R.	3%	3%	12%	Ericsson B.S.	Motorola
GSM 1900 F.R.	25%			Motorola B.S.	Motorola
GSM 1900 E.F.R.				Motorola B.S.	Motorola

QUALCOMM's Preliminary Testing Results[1]

SETUP CONDITIONS:

- CDMA technology on a live but non-commercial QUALCOMM base station
- TTY/TDD modem is electrically coupled to a QUALCOMM mobile through an RJ-11 connection
- CDMA Frame Error Rate (FER) conditions were not measured, but are typically 1.0%
- Sent the message "THE QUICK BROWN FOX..." up to 2,000 times for good statistical averaging
- Tested with TTY/TDD Modems from Ultratec

RESULTS (Character Error Rates=CER):

Baudot (45.45 and 50 baud) modulation

Results are poor (CER= 9% to 16%) and at best reflect those of CDMA testing results from other companies.

V.21 ASCII (300 bps) modulation

Mobile transmitting: CER is much less than 2.35%
The faster baud rate reduces the dependence of the Character Error Rate (CER) on the underlying Frame Error Rate (FER). This explains why the results are better than those of the slower baudot modulation.

Mobile receiving: CER is worse
Poor performance could be a result of the vocoder dropping below full-rate. The baudot signals coming through the PSTN are not always strong enough to lock the speech encoder at full-rate.

---

[1] Submitted by Nikolai Leung [nleung@qualcomm.com] via electronic mail on June 22, 1998.

Philips *Aeon* TTY Interoperability Test Report

Testing with the Lober & Walsh *Mobility* TTY Device

Jim DeLoach

Version 0.01

23 June, 1998

Doc No: TBD

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APPENDIX A – CTIA PUBLISHED TEST SCRIPT A-1

APPENDIX B – TEST DATA B-1

List of abbreviations

BACTC	Bay Area Cellular Telephone Company, the A-side cellular provider in the San Francisco Bay Area (a.k.a Cellular One)
BER	Bit Error Rate
CTIA	Cellular Telecommunications Industry Association
FCC	Federal Communications Commission
FSK	Frequency Shift Keying
PCC	Philips Consumer Communications
RF	Radio Frequency
RSSI	Received Signal Strength Information
SP	System Provider
TTD	Text Telephone Devices
TTY	Teletype

List of references

[1] TTY Test Procedure, Cellular Telecommunications Industry Association, Joint Task Force, Working Group 1/3, 12 February, 1998

1. Introduction

The 1996 Telecommunications Act requires that telecommunications devices provide access to the disabled. Consequently, the Federal Communications Commission (FCC) has implemented new regulations mandating interoperability between Teletype (TTY) Text Telephone Devices (TTD) for the deaf, and cellular telephones. *Digital* cellular telephones are required to provide this support by 1 October 1998.

TTY devices transmit data using Frequency Shift Keying (FSK) passed through a telephone's audio passband. Since digital cellular vocoders are optimized for voice, and tend to distort the sinusoids found in FSK signalling, many have expressed concern that TTY transmissions will suffer considerable errors over digital channels. Additional phenomena unique to cellular channels may also cause errors including: noise and lost frames from Radio Frequency (RF) fading, and interruptions in audio continuity caused by handoffs.

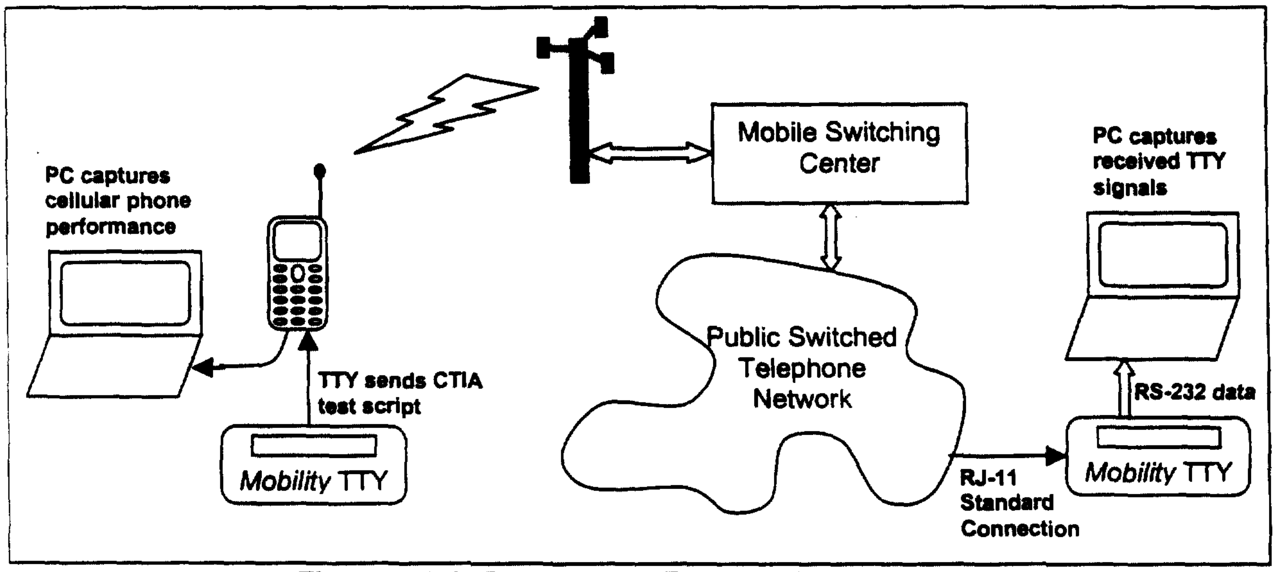
In an effort to characterize TTY performance over realistic IS-136 digital cellular channels, Philips Consumer Communications (PCC) has conducted a series of live-network tests using the Philips *Aeon* IS-136 digital cellular telephone with the Lober & Walsh *Mobility* TTY device. Lober & Walsh claim to have developed an enhanced TTY modem that works better then existing devices by pre-conditioning the transmitted FSK signalling, and by implementing an enhanced demodulator that partially compensates for vocoder distortion for received FSK signalling.

Live calls were made using the Bay Area Cellular Telephone Company (BACTC) Network (a.k.a. Cellular One) in the San Francisco Bay Area. This report presents PCC's findings to date.

2. Test Methodology

2.1 Test Setup

Figures 2.1-1 and 2.1-2 show block diagrams of the test setup for the reverse audio path (audio from the cellular phone to the land phone), and forward audio path (audio from the land phone to the cellular phone). In both cases, one TTY device is using the Aeon cellular phone while the other is using a standard phone line.



30

Figure 2.1-1 Test Setup – Reverse Audio Path

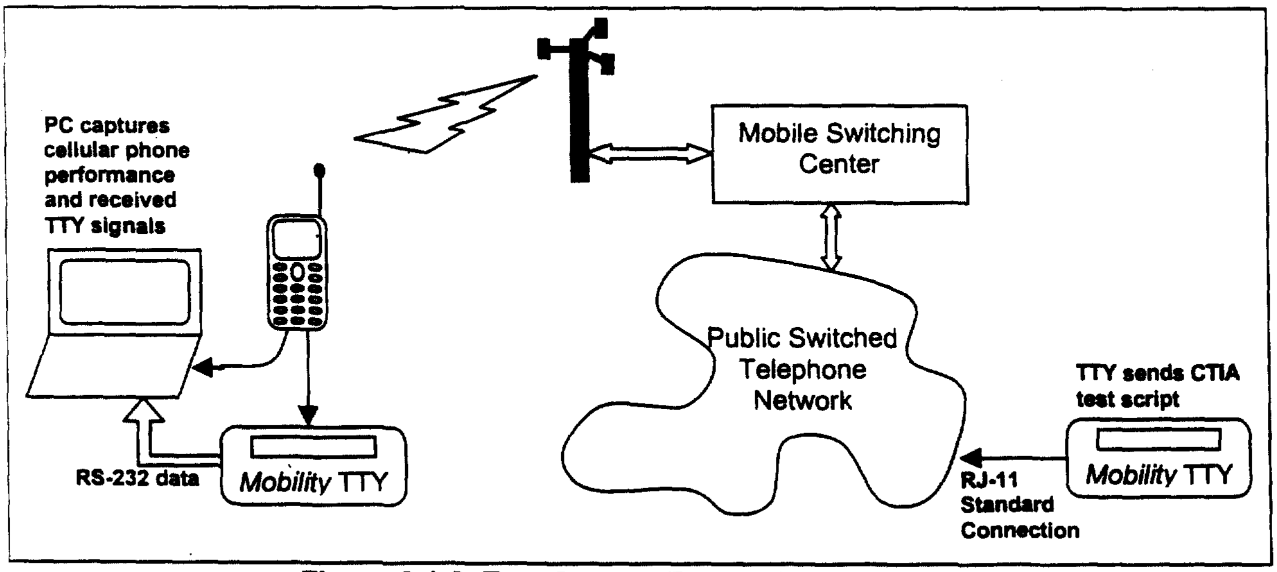


Figure 2.1-2 Test Setup – Forward Audio Path

An audio path is established – either using a digital IS-136 or analog AMPS voice channel – and the sending TTY transmits 45.45 baud baudot TTY characters per the CTIA published test script shown in Appendix A using a built in test command available on the Lober & Walsh *Mobility* TTY unit. This script contains random letters and figures characters plus several typical E911 exchanges. The receiving TTY receives the data and transmits it to a lap-top PC using an RS-232 data connection available on specially configured *Mobility* units. The PC connected to the receive TTY unit captures the received text using the HyperTerminal program. An external antenna (Radio Shack PN: 17-318) was used with the Aeon cellular phone to accommodate the interface cabling available at the time of the test.

The transmitted data was sent at **full rate**, instead of half rate (which is when the transmitting TTY leaves small pauses between characters). Full rate represents worse case conditions. Future testing should consider using half rate testing as well since it will very likely result in improved results. The Lober & Walsh *Mobility* TTY unit is capable of sending either full rate or half rate tests via its test mode.

Received text files are assessed using the "score" program provided by Lober & Walsh. This program is fed a file with the known true text (shown in Appendix A), and the received text file. It correlates the two files and determines the error rate, as well as the number of characters: sent, correctly received, added, missing, and changed. The error rate equals the number missing or changed divided by the total number. The score program considers all characters corrupted by letters/figures shift problems to be errors.

A proprietary Philips program is used to configure the Aeon phone (for example to force it to use either a digital or analog voice channel), and to capture performance information such as Received Signal Strength Information (RSSI), Bit Error Rate (BER), and channel number to a file during test calls. Later, these files are processed to characterize call performance.

2.2 Required Equipment

Table 2.2-1 lists the required equipment.

Quantity	Equipment
1	*Aeon* IS-136 Cellular Telephone, with valid subscription on an IS-136 capable network
1	Aeon interface cable (includes audio in, audio out, RF, and data)
2	Lober & Walsh *Mobility* TTY device
1	Custom interface cable for interconnecting Aeon interface cable audio in and out (BNC connectors) with the Mobility TTY RJ-45 jack.
2	Lap-top PCs (one with a PCMCIA serial adaptor for a 2nd serial port)
1	Cellular antenna, magnetic mount, 3dBi gain, Radio Shack PN:17-318
1	Standard POTs phone line
1	Score.exe program, available from Lober & Walsh
1	CTIA published test script file (text shown in Appendix A)

Table 2.2-1 Required Equipment

3. Test Results

Measurements were taken in four locations or scenarios, each using the live, Bay Area Cellular Telephone Company IS-136 network:

- Ideal signal strength conditions, fixed location
- Moderate signal strength, fixed location (the author's home in Sunnyvale, California)
- Moderate to low signal strength, fixed location (the author's office in Fremont, California)
- While driving in the Fremont / Milpitas / North San Jose, California area

Since signal strength conditions are far from ideal in the PCC Fremont building, ideal conditions were simulated using a directional antenna on the roof pointed at a nearby cell site – thus achieving –60 to –70 dBm RSSI and simulating a phone relatively close to a cell site. The cabling available at the time the collects were taken required the use of an external antenna. It was placed indoors near the phone under test in the fixed location tests, and on the roof of the car for the driving tests.

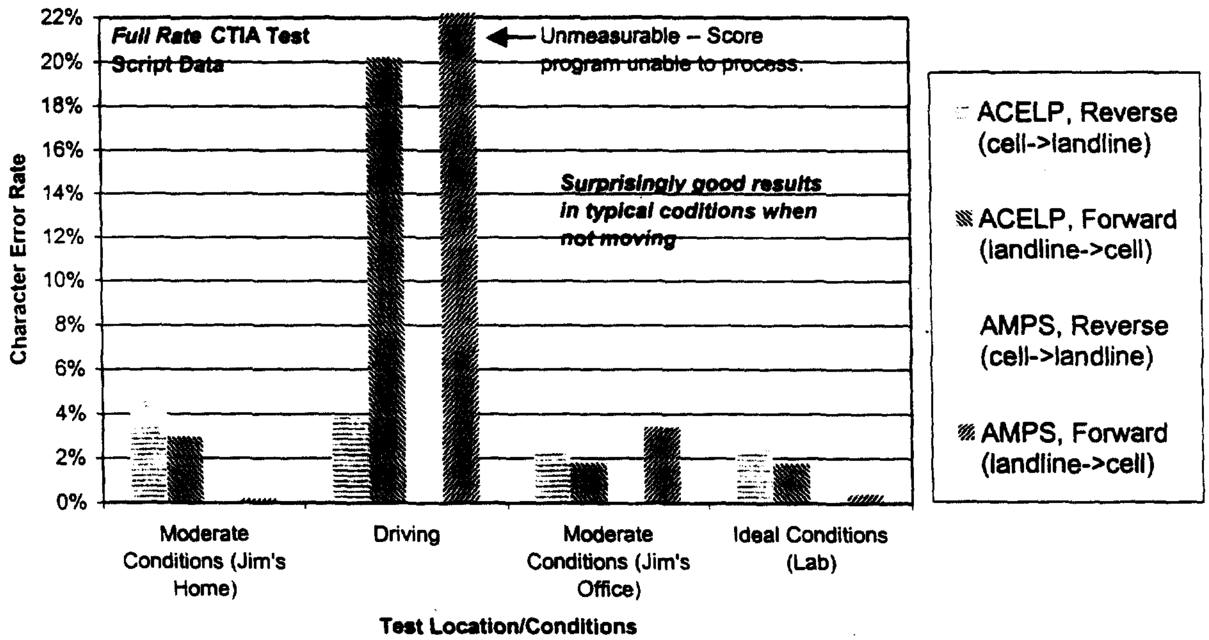


Figure 3-1 TTY Performance Summary

In each location/scenario, measurements were made channel type permutations:

- Digital ACELP Vocoder, Reverse Voice Channel (cellular phone -> land line)
- Digital ACELP Vocoder, Forward Voice Channel (land line -> cellular phone)

- Analog (AMPS) Reverse Voice Channel (cellular phone -> land line)
- Analog (AMPS) Forward Voice Channel (land line -> cellular phone)

Figure 3-1 shows the TTY character error rate using the full CTIA Test Script data, transmitted at Full Rate, measured for each location/scenario, for each channel type permutation. Appendix B shows full performance details for each collect.

Figures 3-2 and 3-3 characterize the cellular channel observed during these tests in these four locations/scenarios. Figure 3-2 shows the maximum, minimum and average RSSI observed by the Aeon phone during each test. As expected, greatest variation in RSSI is seen in the driving scenario, and least variation is seen in the ideal conditions scenario. The RSSI while driving is sometimes very high, no doubt because the drive route loops around the BACTC cell site at the corner of I-880 and Hwy-237. Interestingly, the RSSI observed on analog voice channels is typically several dB lower then on digital channels.

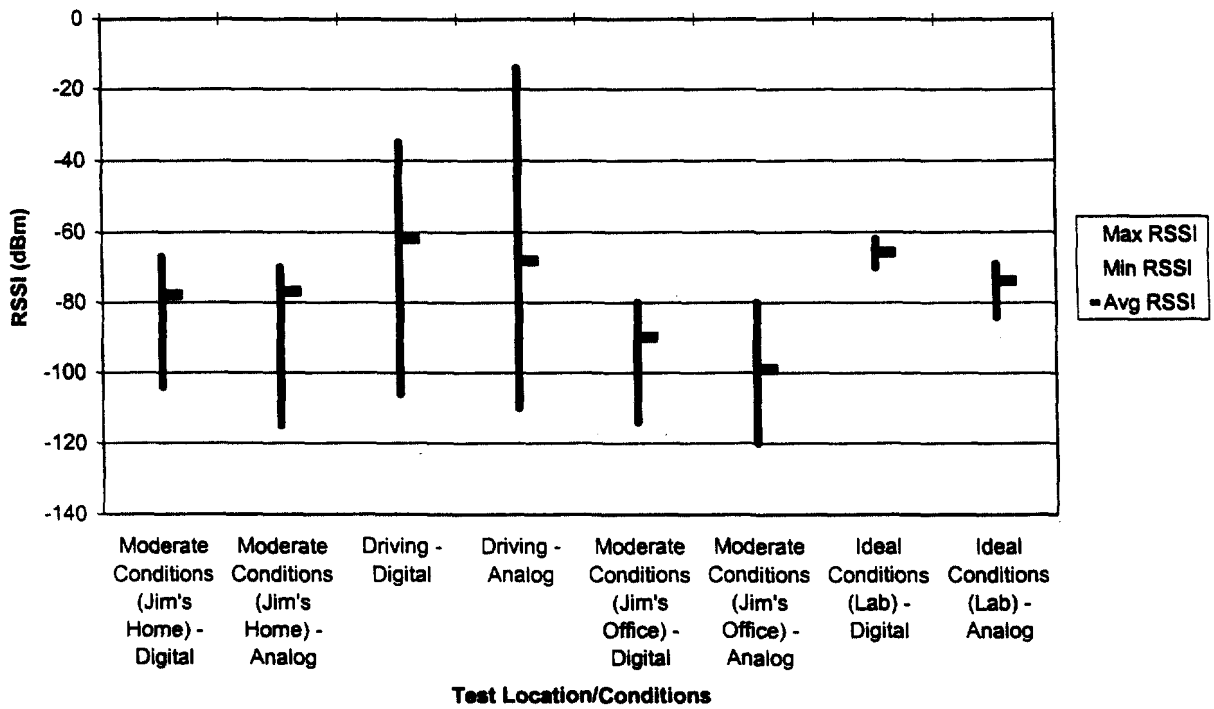


Figure 3-2 RSSI Observed During Each Scenario

Figure 3-3 shows the percentage of time during each digital test that was spent in each Bit Error Rate (BER) range. This chart clearly illustrates why performance suffers so much while driving. Despite relatively good RSSI when driving, BER clearly suffers, and TTY character error rates suffer accordingly. Also, 13 to 20 handoffs were observed in each driving test.

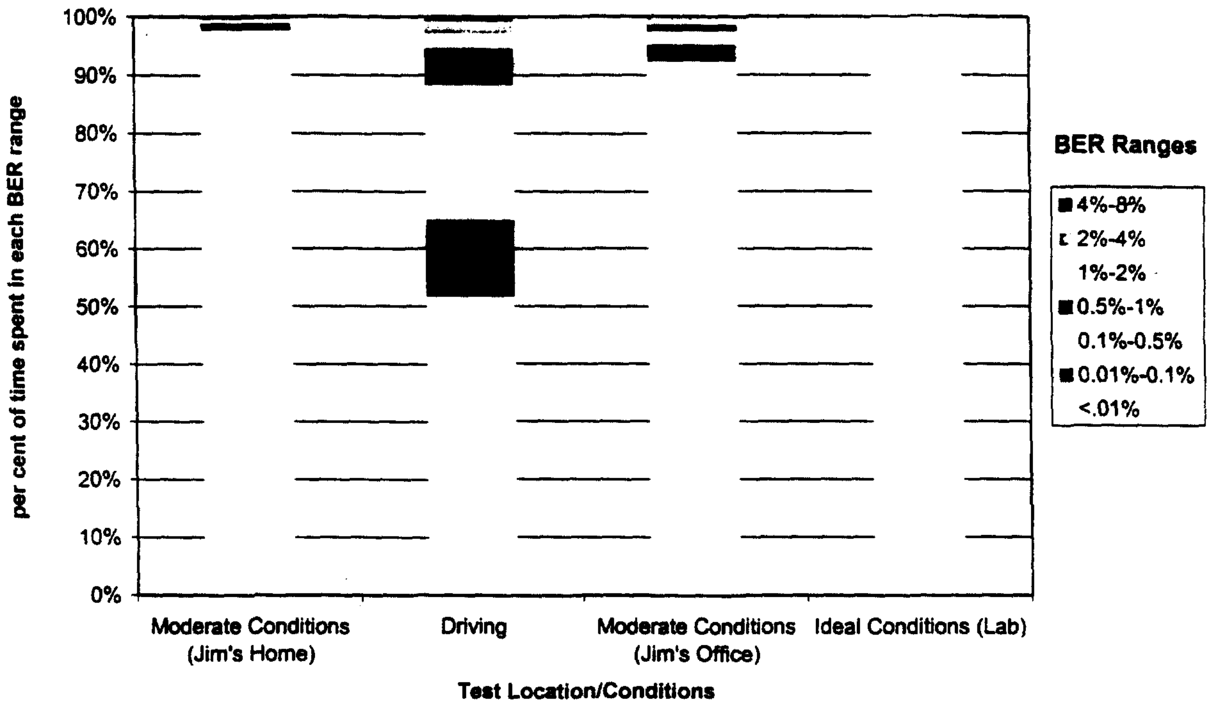


Figure 3-3 BER Observed During Each Digital Scenario

3.1 Failure Modes

No effort was made to quantify how many errors came from each possible cause, however several failure modes stood out.

3.1.1 Loss of Character Synchronization

The following actual received text sample illustrates this problem:

--------------------,,(,,,,,,,,,,,,,,,,,,,,,(,,,,,,,,,,,,,,8,-

This sample is supposed to be a row of dashes. However in this example, the TTY receiver lost alignment, failed to properly recognize the true start and end of each character, and the error propagated for 40 characters. This problem is seen all the time, even in relatively good conditions. Lober & Walsh advise that this problem can be considerably improved by adding pauses between the characters, which helps the receiver stay aligned. They call this "Half Rate" because every other character is a blank. This of course would halve throughput. ***Future testing should evaluate if using Half Rate improves character error rate.***

3.1.2 Letters / Figures

TTY devices use baudot code, a 5-bit code that has two modes: "letters" and "figures". Two special characters are sent to transition from letters mode to figures mode, or visa versa. If these special characters are corrupted during transition, or another character is misinterpreted, then all the following characters will be incorrectly interpreted until the next transition character is received. The following actual received text sample illustrates this problem:

```
7101 YATES AVENUE NORTH, ?499()6, 0-4(
```

What should have been received is:

```
7101 YATES AVENUE NORTH, BROOKLYN PARK
```

This problem occurs frequently, even in relatively good conditions. This appears to be an inherent problem with baudot code that has no good solution.

4. Conclusions

- Using the Aeon cellular phone and the Mobility TTY device in a live network, TTY performance is reasonably good on IS-136 ACELP digital channels – from 2% to 5% character error rate -- ***when operating from a fixed location,*** and is arguably acceptable.
- Only the Mobility TTY device was tested. No statement can be made about performance of other units, or about performance when a Mobility is used to communicate with a different unit.
- Performance while driving is erratic and generally not very good for either digital or analog channels.
- Analog channels out-perform digital channels, and should be used where available, even if digital channels could be used.
- Loss of character synchronization is a key failure mode that is likely to be improved by delaying the rate at which characters are sent, such as by using "Half Rate" transmission.
- Additional tests are needed to:
  - assess the improvement from "Half Rate" transmission,
  - assess performance of other TTY manufacturers' equipment,
  - assess performance when operating between TTY devices of different manufacturers.